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IN WATER

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Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1957

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*Presented at 4th Ontario Industrial Waste Conference,
Honey Harbour, Ontario, Canada, June 9-12, 1957*

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Estimates based on "population equivalents"⁽¹⁾ rate industrial wastes as responsible for more than twice as much stream pollution in the U. S. as municipal sewage discharges. It has been further estimated that between 1950 and 1975 population will increase by about one third and industrial production will double. Estimates by chemical industry⁽²⁾ of future expansion make these statements on industrial growth seem highly conservative. Production increase will obviously be accompanied by increasing use of water.

The future growth of water use is likely to occur in a frame-work of shrinking availability of surface water. Supplementary irrigation in areas which formerly depended solely on rainfall is increasing rapidly. This consumption of water occurs during dry summer periods, when most streams have their lowest flow of the year, and it has been estimated⁽³⁾ that it can use the entire flow of many streams, even if only a small fraction of 1% of the land in a watershed is irrigated.

Municipal use of water is increasing faster than population. Thus, the average urban dweller now uses 150 gallons of water daily, whereas 30 years ago he used only 20 gallons⁽⁴⁾. Recreational use of water is harder to assess, but both increased leisure time and increased income are causing the public to demand more water resources for recreation.

Requirements for discharge of wastes to surface waters will, of necessity, become increasingly critical, and one of the most critical items is likely to be the taste and odor imparted to water by organic materials in wastes. In 1948 there were 422 water plants in the U. S. serving communities having populations in excess of 25,000; 133 of these communities with a population of about 14,000,000 included some provision for taste and odor control in their water plants⁽⁵⁾. In 1954, there were 570 water plants serving communities having populations in excess of 25,000; 201 of these plants serving about 34,000,000 people included facilities for taste and odor control⁽⁶⁾. This well defined trend in water plant facilities and practise clearly indicated the rapidly increasing pressures and costs borne by water plants because of impairment of raw water quality by odorous material.

The total taste and odor problem has many facets. A severe and sustained drought forced Dallas, Texas to supplement a normally adequate municipal water source with unsuitably salty water. The same drought caused Chanute, Kansas to fall back on treated sewage effluents as a raw water supply in order to keep water in its faucets. The tainting of fish flesh by chemicals in surface waters is another type of taste and odor problem. In streams and lakes the biological synthesis of chemicals causing taste and odor is becoming more important because of man-caused increases in stream fertility. These are all matters for serious concern. This discussion will, however, limit itself largely to

consideration of chemical impairment of water quality for municipal or industrial use.

Sources of Tastes and Odors

Odors may be attributed to chemical materials produced by biological growths and to the presence of organic pollutants or other objectionable matter naturally present in the water. The distinction is not clear-cut as the introduction of a pollutant may greatly stimulate the growth of objectionable organisms. Chemical oxidation of carbonaceous material increases the supply of carbon dioxide, which stimulates organic growth. Nitrogen and phosphorus from sewage also stimulate the growth of photosynthetic organisms.

Incredibly small amounts of many odorous materials can cause sensory stimulation. Experiments in the SEC laboratories have frequently yielded a detectable odor from recovered materials in concentrations of 2 parts per billion and less. Sometimes materials have been isolated (but unfortunately not identified) which could be detected by odor in concentrations as low as 10 parts per trillion. Very substantial odors, therefore, can be caused by extremely minute amounts of such material. In terms of quantities that are easier to visualize, a single teaspoonful of pollutant can impart odor to 1 million gals. of water.

Utilizing adsorption and extraction techniques for concentrating the odorous organic pollutants of drinking-water supplies, it has been found that neutral compounds are usually the most abundant odorous organic pollutants. These neutral organic materials

usually have intense tastes and odors. The second most abundant group of odorous materials is usually the organic acids, which also have intense odors and tastes. Small quantities of other materials have been recovered, including organic bases (which may have a tobacco-like odor), water-soluble compounds (which frequently have caramel-like odors), and a group usually referred to as the "weak acids," which include phenolic compounds, if they are present in the water.

Phenolic compounds are present infrequently and have probably been over-emphasized because they are one of the few materials detectable by analytical techniques generally available in water plant laboratories. Before chlorination, commonly occurring phenolic materials have but little taste or odor. Ordinary chlorination of these materials greatly increases the taste and odor; free residual chlorination destroys the odor.

Characteristics of Tastes and Odors

Odors are subject to seasonal cycles. Industrial pollutants show reasonably well-defined patterns of behavior and may be divided into two general categories, depending upon whether they are susceptible or resistant to biological destruction during transportation in surface waters.

1. With pollutants subject to biological destruction, odor intensity is likely to reach a peak during the winter months. Unless the water plant is immediately adjacent to the source of pollution, the peak winter odor intensity is likely to occur when the river undergoes a moderate rise, especially after a period of low

water. This is caused by a combination of scouring of bottom deposits and more efficient transportation of dissolved materials. Although the rise in the river increases the amount of dilution water, the reduction in the time of travel between the source of pollution and the point of water consumption is likely to result in an over-all increase in the amount of odor-producing material reaching the water plant inlet. Where a river freezes over solidly and perhaps becomes anaerobic in certain areas, maximum odor loads may occur during low-flow periods in the winter.

2. Some pollutants are resistant to destruction during transportation in surface waters. (Fortunately, few odorous materials of industrial origin are in this group). When a water source is polluted by such materials, maximum odor difficulty or other disturbance may accompany any low-flow period.

Algal blooms or spurts of microbiological growth frequently have a definite seasonal incidence and can be expected at reasonably well-defined periods at each locality. Local and regional experience is the best guide available and should be fully explored.

Sometimes algal growth and industrial pollution may take turns as the dominant nuisance in a particular situation. In one water plant studied, phenol from a nearby refinery is present throughout the year, and there is usually a very definite chlorophenolic taste in the water. At certain times of the year, however, algal blooms cause tastes and odors of such intensity that the phenol odors are not noticed.

The river flush-out is sometimes the cause of acute taste and odor problems as well as other stream disorders. For example,



it was recently observed⁽⁷⁾ that organic wastes from a refinery were not transported by the receiving stream and apparently were subject to bottom storage with very incomplete self-purification. Periodic river rises flushed out the bottom deposits. In our experience some of the most severe water quality problems have been frequently associated with the first river rise after a long, dry spell with the accompanying flush-out of pollutional material retained in bottom deposits. It is believed that such incidents are sometimes wrongly attributed to industrial spillage or dumping.

The taste and odor of a raw water presents a problem at the water plant which must be faced on several fronts. These include the following considerations:

- (1) The water must be made palatable and acceptable to almost the entire using population.
- (2) Surface supplies must be disinfected to give water of satisfactory bacteriological quality.
- (3) The cost of high quality water must be compatible with the ability of the community and its industrial consumers of "city" water to pay for the water.

The control of water quality by water treatment has been discussed recently by Ettinger and Middleton⁽⁸⁾ and presentation of this material is beyond the scope of the present discussion. It is appropriate, however, to discuss simple approaches to the evaluation of the odor-producing potential of organic wastes. To do this intelligently it is necessary to take at least nominal

cognizance of the nature of water treatment procedures currently in use.

Water supplies taken from surface sources subject to pollution almost invariably are chlorinated and the taste and odor of the water after chlorination become important factors. Chlorine frequently reacts with organic material to develop or decrease odor. When this occurs the odor intensity will vary with the amount of chlorine added. Schematic presentation of this pattern of behavior is shown in Figure 1. The reactions occurring between chlorine and waste components are sometimes influenced by dilution. Since water treatment plants cannot handle extremely polluted water such as an industrial waste stream, the organic waste under consideration should be suitably diluted to concentration levels approximating those handled by a severely loaded water plant. Chlorine reactions produce acid, making it desirable to buffer the solution being chlorinated with sodium bicarbonate, thus simulating the bicarbonates which buffer natural waters. In large water distribution systems, a long period elapses between the time water leaves the treatment plant and the time it reaches the most distant consumer. Odors which develop in a water distribution system as the result of slow reactions between residual chlorine and organic contaminants must be given due consideration.

Odor is necessarily a subjective quantity, amenable to measurement and interpretation only in terms of people. This requires that odor test procedures and their interpretation be based on the characteristics of the reactions of people to odors.

Figure 2 shows a log-probability chart of the variation in the amount of a specific chemical, n-butyl alcohol, required to give a detectable odor in a series of 705 tests made by 33 water-plant operators over a five-month period. This chart leads rather simply to certain interpretations. In reaction to the n-butyl alcohol, the most sensitive five per cent of the population is at least seventeen times as sensitive as the least sensitive five per cent. The "fifty-per cent" man, or median observer, has less than one-quarter the sensitivity of the most sensitive five per cent, and is more than four times as sensitive as the least sensitive five per cent of the population.

Obviously, any attempt at quantitative appraisal of odor requires a large random group of observers, or a panel of several people selected because they show at least reasonably good capacity for odor detection in general. The most meaningful value with a small panel is the panel median I.O. Use of the "median" prevents one unusually dull or unusually sensitive observer from throwing the panel results too far one way or another. If a mean is used it should be the geometric mean.

There is no real advantage in attempts to characterize odor-strength too precisely. In the laboratories of the Sanitary Engineering Center we do not attempt to differentiate between odor intensities of solutions that differ by a concentration factor of less than two.

Observers have further characteristics which require consideration in a prescribed test procedure. They tend to lose

sensitivity when asked to detect a trace of a material after exposure to a gross quantity of the same material. Because observers are suggestible, it is difficult to secure an impartial judgment without asking the observer to discriminate between unknowns and a blank. Fatigue and boredom combine to make observers less sensitive and more erratic during prolonged odor observations. Further details of our ideas on odor and taste-testing protocol have been described elsewhere⁽⁹⁾ and need not be repeated here.

Another facet of the problem of assaying the odor-producing potential of wastes lies in the question of whether or not odors are additive. To over-simplify, assume (1) a chemical plant has only two odorous plant waste streams, one of which contains only an organic alcohol, and a second which contains only a pyridine base; (2) that the total plant stream enters a body of water in which neither compound will be sufficiently concentrated to give a detectable concentration on the basis of concentration in the waste stream.

Questions to be answered are:

- (a) Are the waste streams unimportant in terms of stream odors since they will be present below threshold concentration?
- (b) Can both waste streams together give the stream an odor increase if neither one can do it alone?

Assuming that chemical reactions are not involved, the answer to the questions above lie in the determination of whether odors stimuli by unrelated individual materials are additive and/or synergistic or whether they are non-additive and/or antagonistic.

If it be assumed that the threshold concentration of material A is "a" and the threshold concentration of material B is "b" the question posed by the statement:

$$\frac{a}{2} + \frac{b}{2} \approx \text{TCC}$$

where TCC is the threshold odor concentration.

Investigation of this question is just getting well underway in the S&C laboratories. So far we have measured human response to odor stimuli by combinations of two and three specific chemicals at a time, but only a limited number of chemicals have been investigated. To date our findings give the answer

$$\frac{a}{2} + \frac{b}{2} \approx \text{TCC}$$

We have little reason to believe that this finding will not hold up in most circumstances and it represents the best basis presently available for considering the questions involved. In words, the mathematical notations say that human sensory response to individual odorous chemicals in a mixture is at least additive and that it may be greater than an additive response.

Accepting this premise, the questions listed previously can now be answered.

- (a) The hypothetical waste streams suggested previously are important to stream odor quality because they join with other materials to increase the total odor load even though the waste streams individually will not add a threshold concentration of the chemicals they contain.

- (b) Even though waste streams are unlike in odor or chemical structure and do not react, the two streams can jointly impart detectable odor to the receiving stream even though neither one can do it alone.

The additive or even synergistic character of odor stimuli is important in approaching such complicated situations as those presented by the boundary waters. Few plants can be charged with contributing enough organic material to give detectable taste and odor to 175,000 sec ft of water. Each waste source must, however, be regarded as a definite contributor to total impairment of odor quality.

CONCLUSIONS

The evident trend in the taste and odor quality of raw water is downward. Estimates of stream pollution in terms of population equivalents show an ever-upward trend. Taste and odor loads may be expected to increase more rapidly than loads in terms of "population equivalents" because of many factors, some of which have already been discussed.

Subject to relief by self-purification in streams, organic pollutants of surface waters present an additive assault on water quality, and each tangible organic source is a factor in determining the odor of the resulting water.

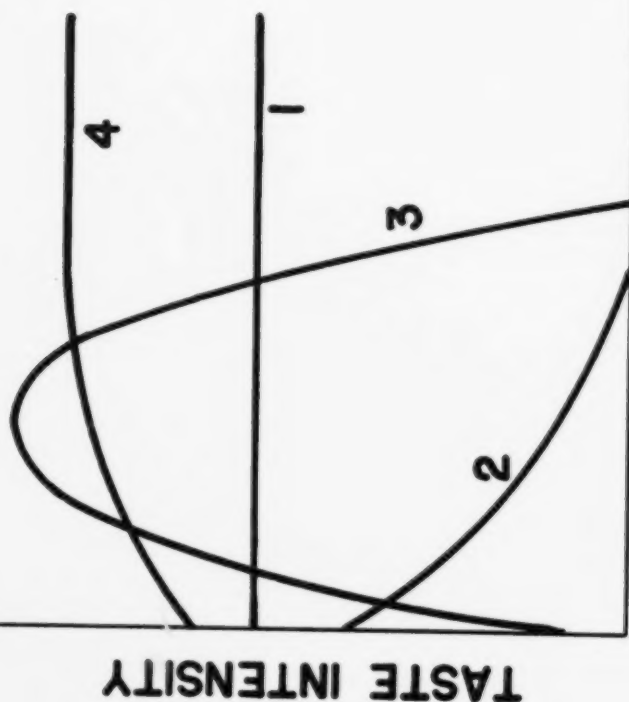


BIBLIOGRAPHY

1. Secretary, Department of Health, Education and Welfare, Statement before Subcommittee on Flood Control, Rivers, and Harbors, Senate Committee on Public Works, April 22, 1955.
2. Manufacturing Chemists' Association, Washington 6, D. C. "Chemical Industry Facts Book," 2nd ed., 1955.
3. Wiseman, J. W., Sewage and Ind. Wastes 27, 1284 (1955).
4. Hollis, M. D., Publ. Health Reports, 71, 436 (1956).
5. Thoman, J. A., "Statistical Summary of Water Supply and Treatment Practices in the United States." Pub. 301, USPHS, Washington, D. C. (1953).
6. Porges, Ralph, compiled from "Municipal Water Facilities, Communities of 25,000 Population and Over, Continental United States as of December 1954." USPHS, Washington, D. C. (1954).
7. Ludzack, F. J., Ingram, Wm. Marcus, and Ettinger, M. B., "Characteristics of a Stream Composed of Oil Refinery and Activated Sludge Effluents." To be presented before the 31st Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference, June 21, 1957.
8. Ettinger, M. B., and Middleton, F. M., Journal Amer. Water Wks. Assn., 43, 1265 (1956).
9. Ettinger, M. B., Sewage and Ind. Wastes, 28, 1116 (1956).

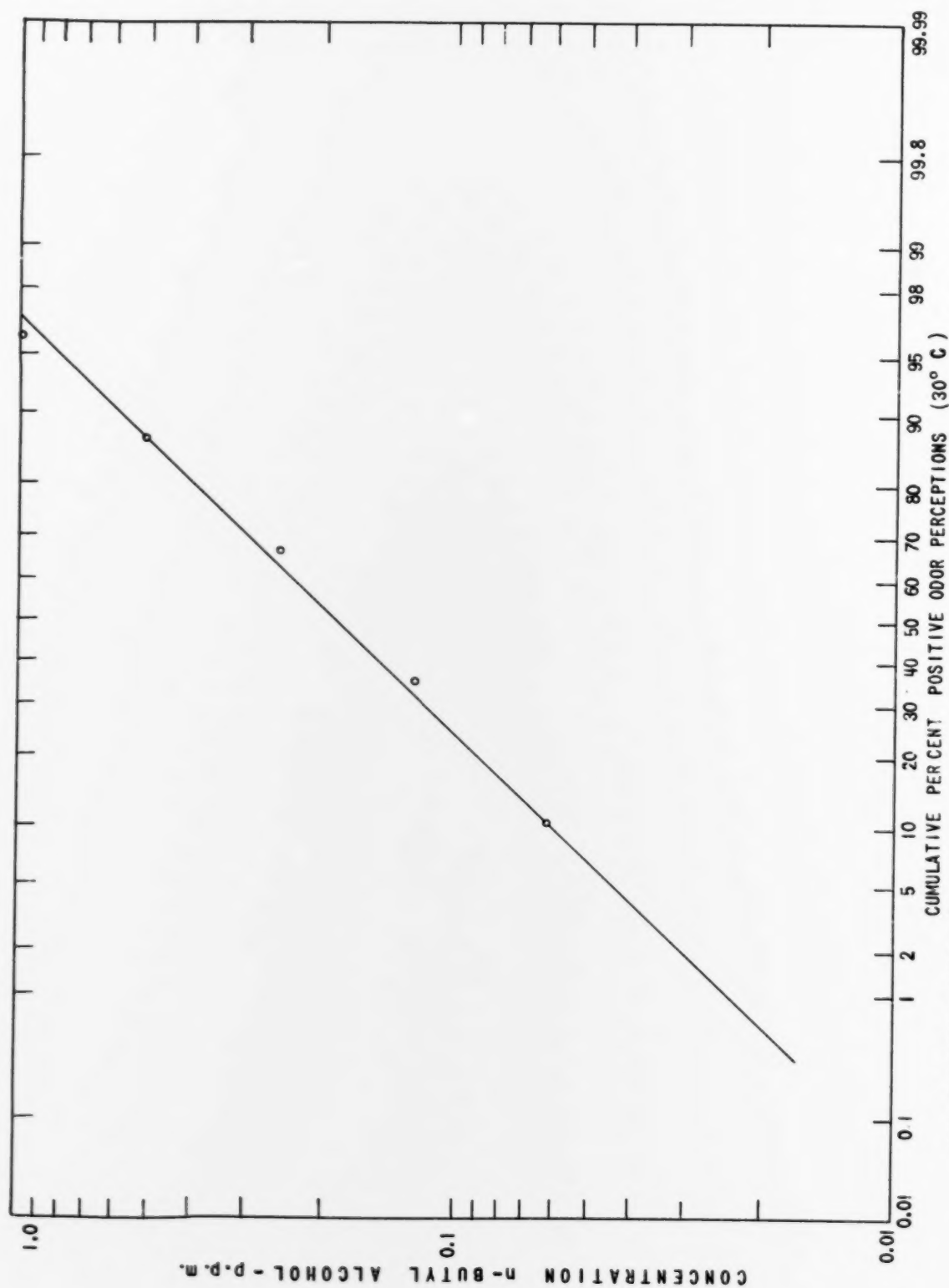
SOME EFFECTS OF CHLORINATION ON THE TASTE INTENSITY OF DILUTIONS OF INDUSTRIAL WASTES

1. No Effect
2. Continuous Reduction of Taste
3. Increase to a Maximum Followed by Decrease
4. Increase to a Maximum



CHLORINE ADDED

TASTE INTENSITY



CHARACTERISTICS OF OPERATOR RESPONSE TO n-BUTYL ALCOHOL
(785 OBSERVATIONS — 33 OPERATORS)

FIGURE 1